CP Cume 11/14/2005 Answer Key

Ia. $\mu = iA$

if current caused by a charge e, moving with speed v in a circle of radius r, then

period = $2\pi r/v$

$$i = \frac{e}{(2\pi r/v)} \qquad A = \pi r^2$$

$$\mu = \frac{e}{(2\pi r/v)} \pi r^2 = \frac{evr}{2} \cdot \frac{m}{m} = \frac{e \cdot rmv}{2m} = \frac{eL}{2m}$$

from classical to quantum mechanical

$$L = \ell \hbar$$

$$\mu = \frac{e\hbar}{2m} \ell$$

Ib. Neutron is composed of up and down quarks (udd)

Quarks carry charge $u = +2/3\, e$

$d = -1/3\, e$

the charged nature of sub-nucleonic particles produce a non-zero $\mu$ for neutron

Ic. Again, both protons (uud) and neutrons (udd) are composed of quarks. Since nucleons are not point particles, they deviate significantly from the Dirac expectation.

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IIa. $^{2}_{1}H_{1}$, 1 proton
1 neutron

naively, would assume that $\mu$ is combination of spin g factors of proton and neutron

$$\mu = \frac{1}{2}(g_s(p) + g_s(n))$$
$$= \frac{1}{2}(+5.5856 + (-3.826))$$
$$= +\frac{1}{2}(1.7596) = \boxed{0.8798\,\mu_N}$$

IIb.

$$\psi = a_s \psi_{\ell=0} + a_d \psi_{\ell=2}$$

$$\mu = a_s^2 \mu_{\ell=0} + a_d^2 \mu_{\ell=2}$$

IIc. $^{2}H$ measured by molecular beam magnetic resonance method. See Kellogg, Rabi, Ramsey and Zacharias PR 57, 677 (1940)

static magnetic field
varying rf field } search for absorption of rf photons

IId. $^{20}_{10}Ne_{10}$. magnetic moment is zero since all protons and all neutrons couple to $J=0$ in the ground state. (strong p-p and n-n pairing)

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III a. $^{181}_{73}Ta$ $\frac{Q}{e} = +4.20$ barns

What are a + c

2 equations

$$\frac{Q}{e} = \frac{2}{5} Z (a^2 - c^2)$$

$$R^2 = \frac{1}{2}(a^2 + c^2) = 1.2\,fm^2 A^{2/3}$$

$$\frac{4.2 \times 10^{-24}\,cm^2}{73}\left(\frac{5}{2}\right) = (a^2 - c^2) = 1.438 \times 10^{-25}\,cm^2 \times \left(\frac{10^{-2}\,m}{cm}\right)^2 = 1.438 \times 10^{-29}\,m^2$$

$$2 \cdot 1.2 \times 10^{-30}\,m^2 (181)^{2/3} = (a^2 + c^2) = 7.679 \times 10^{-29}\,m^2$$

$a^2 - c^2 = 1.438 \times 10^{-29}\,m^2$ $a^2 = c^2 + 1.438 \times 10^{-29}\,m^2$

$a^2 + c^2 = 7.679 \times 10^{-29}\,m^2$ $= 2c^2 + 1.438 \times 10^{-29}\,m^2 = 7.679 \times 10^{-29}\,m^2$

$2c^2 = 6.241 \times 10^{-29}\,m^2$

$c^2 = 3.1205 \times 10^{-29}\,m^2$

$c = 5.58 \times 10^{-15}\,m$

$a^2 + (5.58 \times 10^{-15}\,m)^2 = 7.679 \times 10^{-29}\,m^2$

$a^2 + 3.1205 \times 10^{-29}\,m^2 = 7.679 \times 10^{-29}\,m^2$

$a^2 = 4.5585 \times 10^{-29}\,m^2$

$a = 6.751 \times 10^{-15}\,m$

$$\frac{a}{c} = \frac{6.751 \times 10^{-15}\,m}{5.58 \times 10^{-15}\,m} = \boxed{1.21}$$

III b. For the numbes 8, 20, 28, 50, 82, 126, there is a large gap in single-~~neutr~~ nucleon shell structure. These "magic" nucleon numbers show extra "stability". Therefore, they are spherical in shape and should have $Q \sim 0$

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IV a.

neutron

size ~ $1\times10^{-15}$ m (1 fm)

charges $u = +\frac{2}{3}e$

$d = -\frac{1}{3}e$ (each)

if full separation of u and d quarks in nucleus, then $d = q z$

q is charge

z is separation distance

$$d = \left[\frac{2}{3} - \left(\frac{-2}{3}\right)\right] e \,(1\times10^{-13}\,\text{cm})$$

$$= \frac{4}{3} e \,(1\times10^{-13}\,\text{cm}) = \boxed{1.33\times10^{-13}\ e\,\text{cm}}$$

(actual size is $< 10^{-26}$ e cm)

IV b. C = charge conjugation symmetry

P = parity change symmetry

T = time reversal symmetry.

CP broken in decay of neutral meson.

∴ T is expected to be broken, if CPT is an exact symmetry.

evidence for neutron EDM would violate T symmetry.